

Abstract

Change detection in dynamic networks is an important problem in many areas, such as fraud detection, cyber intrusion detection and healthcare monitoring. It is a challenging problem because it involves a time sequence of graphs, each of which is usually very large and sparse with heterogeneous vertex degrees, resulting in a complex, high-dimensional mathematical object. Spectral embedding methods provide an effective way to transform a graph to a lower dimensional latent Euclidean space that preserves the underlying structure of the network. Although change detection methods that use spectral embedding are available, they do not address sparsity and degree heterogeneity that usually occur in noisy real-world graphs and a majority of these methods focus on changes in the behaviour of the overall network. In this paper, we adapt previously developed techniques in spectral graph theory and propose a novel concept of applying Procrustes techniques to embedded points for vertices in a graph to detect changes in entity behaviour. Our spectral embedding approach not only addresses sparsity and degree heterogeneity issues, but also obtains an estimate of the appropriate embedding dimension. We call this method CDP (change detection using Procrustes analysis). We demonstrate the performance of CDP through extensive simulation experiments and a real-world application. CDP successfully detects various types of vertex-based changes including (1) changes in vertex degree, (2) changes in community membership of vertices, and (3) unusual increase or decrease in edge weights between vertices. The change detection performance of CDP is compared with two other baseline methods that employ alternative spectral embedding approaches. In both cases, CDP generally shows superior performance.

Keywords: Change detection, Dynamic networks, Sparse networks, Degree heterogeneity, Spectral embedding, Dimensionality reduction, Procrustes analysis